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## The Effects of Molecular Weight, Agitation and Zeta Potential of Retention Aids on Filler Retention

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THE EFFECTS OF MOLECULAR WEIGHT ,  
AGITATION AND ZETA POTENTIAL OF  
RETENTION AIDS ON FILLER RETENTION .

by

Trieu Nguyen

A thesis submitted to the  
Faculty of the Department of Paper Science  
and Engineering  
in partial fulfillment  
of the  
Degree of Bachelor of Science

Western Michigan University  
Kalamazoo, Michigan

## ABSTRACT

When it comes to filler retention , the most frequently studied parameters are : Molecular weight of the retention aid , degree of agitation , and zeta potential .

Alum , as an electrolyte , and various polymers of the same chemical structure , but different molecular weights were evaluated for their performances in retaining  $\text{TiO}_2$  . Different degrees of agitation were introduced to the stock to investigate the effect of turbulence on retention , and , finally , zeta potential was varied to observe its effect .

Higher molecular weight polymer was found to produce better retention . On the other hand , agitation reduced it . Retention seemed to be favorable with zeta potential values close to the iso-electric point or on the positive side .

### ACKNOWLEDGMENTS

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## ABBREVIATIONS

appr. , approximately

Conc. , Concentration

Fig. , Figure

g , gram(s)

M. Wt. , Molecular Weight

ml , milliliter

Ret. , Retention

SCD , Stream Current Detector

Wt. , Weight

Z , Zeta potential

#/T , pound(s) per ton

% , percent

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## INTRODUCTION

In recent years , the retention of non-fibrous materials was intensively studied in an attempt to modify the properties of paper manufactured . At the present time , more than four million tons of such materials are used each year for paper operations . The efficiency of retaining these materials in the sheet is of prior importance , for it affects seriously the cost of the product , the recovery system , the efficiency of the whole paper making operation ; and , most of all, the problem of pollution , which threatens the environment recently .

One of the most important discovery in paper making must be the discovery of the use of chemicals as retention aids , or flocculants . The effectiveness of these chemicals , however , depends greatly on many parameters associated with the process of paper making .

This paper will review several major factors which control the efficiency of retention aids in filler retention . These are : molecular weight of the retention aid , stock agitation , and zeta potential . The mechanisms of retention is also discussed as well . And an experiment will be carried out as an attempt to verify the theories .

## LITERATURE REVIEW



There have been many researches and experiments made in order to study the one-pass retention of fillers during the sheet formation process . This is a complicated matter and it would help a lot to take a brief look first at an aqueous system of dispersed filler particles in the pulp stock .

Very generally speaking , the particles have a mutual repulsive force among one another , This force keeps one filler particle from moving close toward another . Therefore , there is little chance for the particles to form flocs which enable the retention of the fillers in the sheet . Various treatments could be done to the system to improve the retention according to different theories discussed in the following sections .

#### THE EFFECT OF THE MOLECULAR WEIGHT

The role of molecular weight of additives used as retention aids is <sup>9</sup>crucially important in the process of retaining fillers . Linke (1) pointed out that the ability to flocculate particles is directly related to the molecular weight of the flocculant .

Let us now investigate more thoroughly the behaviors of low and high molecular weight flocculants

in the filler-fiber system .

### LOW MOLECULAR WEIGHT FLOCCULANTS

Although the dispersed fillers in the pulp system may stick together under the mutual attraction forces , the " bonding " is very unstable and the particles could be easily redispersed into the solution . This attraction force , namely , the VanDer Waal force between particles , is of insignificant magnitude to hold two filler particles together , against the repulsive force due to the charge on the surfaces of the particles . In some cases , a merely shaking action is enough to cause the particles to break down (2) .

It was found that the retention of the fillers could be greatly improved with the addition of simple electrolyte salts . There are numerous electrolytes that could bring about almost one hundred percent retention under static condition . In deed , Britt (2) developed a Two-Step method which could effectively increase the tenacity of coagulation , or to express in another way , improve the wet bonding between pigments and fibers , up to one hundred percent ; this is , however , only an experiment done in the laboratory , under static condition , of course . The method is done

by reacting the pulp slurry with a cationic electrolyte . Subsequently , a precise amount of anionic electrolyte is added to the stock at head-box consistency preferably .

Coagulation , the word used to denote the bonding among filler particles resulted from the use of electrolytes , as opposed to the word flocculation denoting the effect resulted from the use of polymers ; occurs as the positive ions of the electrolyte adsorb to the negative charged surface of the filler particles and thus reduce the repulsion among particles in the solution . This is a surface-charge-control phenomenon described by Walkush (3) . This type of floc is, however , characteristic of its susceptibility to mechanical disturbance . Any hydrolic shear incident to sheet formation will redisperse the flocs. This is why it is sometimes called soft flocs . The above process is named Physio-Chemical process . The effectiveness of electrolytes depends upon two factors : the chemical valency and the concentration of the ions . Schulze and Harley (4) stated that the higher the valence of the precipitating ion , the greater the coagulating power . As for the concentration , increasing amounts of electrolyte would increase the coagulation until the repulsion potential is eliminated , additional electrolyte

has no more effect . It has been noticed that electrolytes of this type are not used alone as retention aids because of the low efficiency . Usually , some kind of high molecular weight polymer is employed in addition to the electrolyte for maximum efficiency .

### HIGH MOLECULAR WEIGHT FLOCCULANTS

The discovery of the use of high molecular weight polymers as retention aids has markedly solved the problem of filler retention .

Although two polymers could have the same total chemical composition - that is , their carbon , hydrogen , oxygen and nitrogen linkage in the polymeric structures is the same - their sizes and shapes could be very different . They could be long or short , branched or linear ( Fig. 1 ) . This simple difference could , strangely enough , change dramatically the effectiveness of the polymer on the filler retention .

Here , the physical entanglement - or , the mechanical mechanism - becomes to play an important part , in addition to the bridging action . As a matter of fact , Mason (5) believes that flocculation is majorly caused by physical entanglement , especially in a moving fluid . The Physio-chemical mechanism is not a

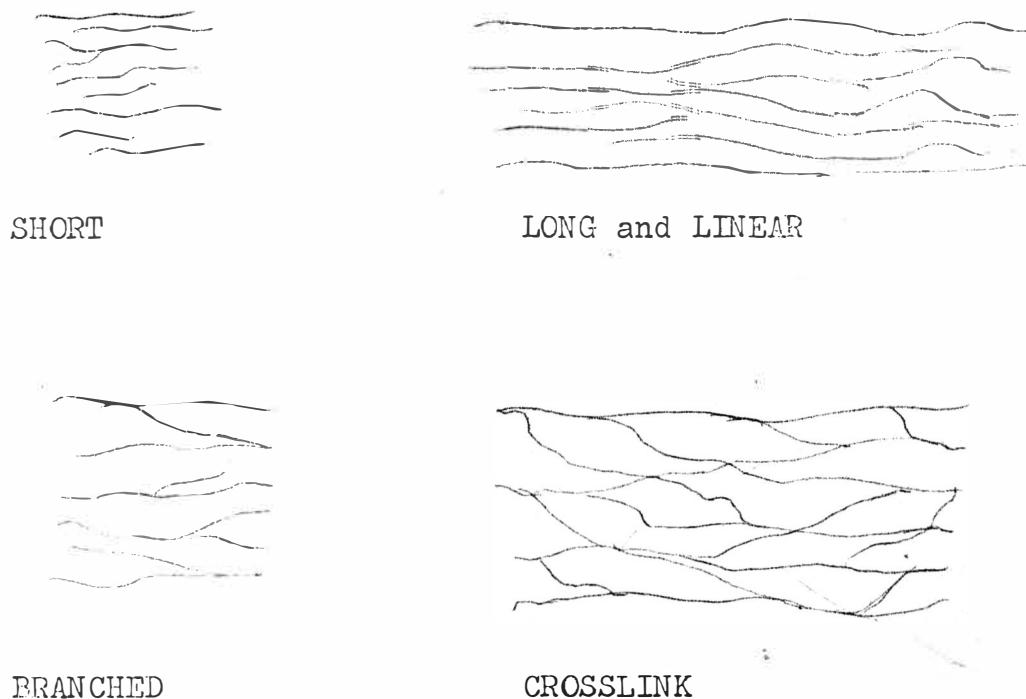


FIGURE 1

significant factor in this case . The most believed theory is the Bridging action , developed by Lamer and co-workers (6) . According to this theory , flocculation is caused by the connection of the long polymer chains : a segment of a very long molecule adsorbs onto the surface of a filler particle , leaving a large portion of the molecule free to be adsorbed onto another particle or fiber , forming an actual molecular linkage between particles and fibers ( Fig. 2 ) . A lot of

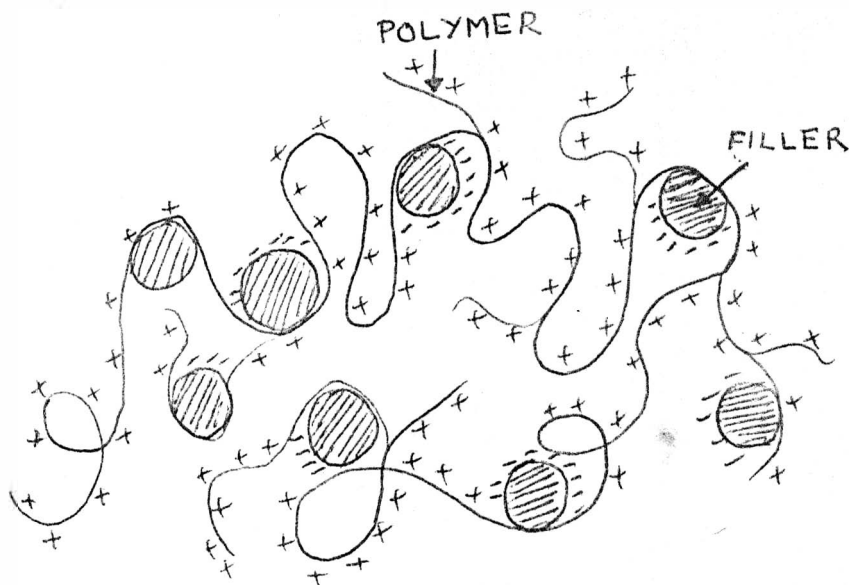


FIGURE 2

authors seem to agree that the adsorption of a polymer onto a surface is more energetic than it would be for a monomer having the same functional group . Each molecule is bonded to the surface of a fiber , for example , at a large number of individual sites , and so the accidental breaking of some of the bonds will not necessarily affect the polymer linkage . Also , the length and the three dimensional shape of the polymer will help to retain a relatively large weight of material at a given bonding site (Fig. 3 ) .

Koral (7) , in a study of the adsorption of polymers , concluded that " the amount of polymer ad-

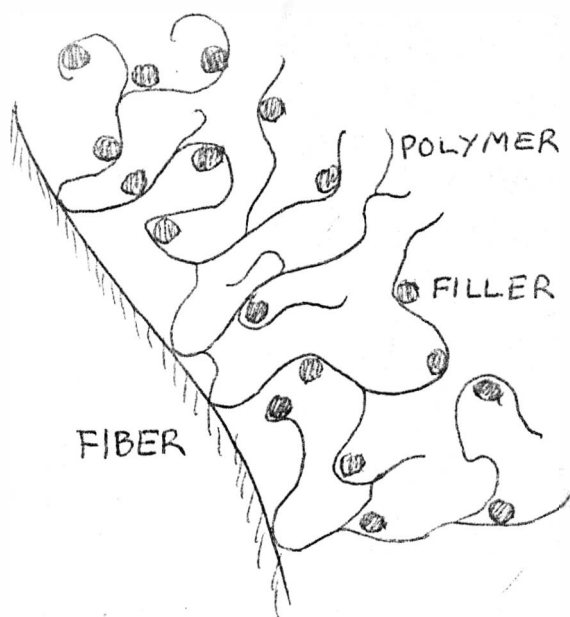


FIGURE 3

sorbed increases with molecular weight and that the dependence on molecular weight is more pronounced in a poor solvent than in a good solvent . " . He also showed that the adsorption of fractionated polymers is uniformly greater than unfractionated polymers of the same type .

In a recent study , Arvela (8) revealed that an increase in molecular weight produced an increase in filler retention . Depending on the molecular weight , the flocculation could be described step by step (1) : At low molecular weight , flocculation is hardly noticeable , as the molecular weight increases ,

the retention of fillers , fines is evident , and the white water is clearer . At very highmolecular weight , freeness is increased .

The flocculation action of polymers , though it is efficient without other aids , could be much more effective with the presence of alum , which enables the connection between fibers and polymers since polymers do not adsorb onto the surface of fibers as readily as they do onto the surface of fillers ( Fig. 4 ) .

This type of floc is also sensitive to the concentration of polymer added to the stock , There is

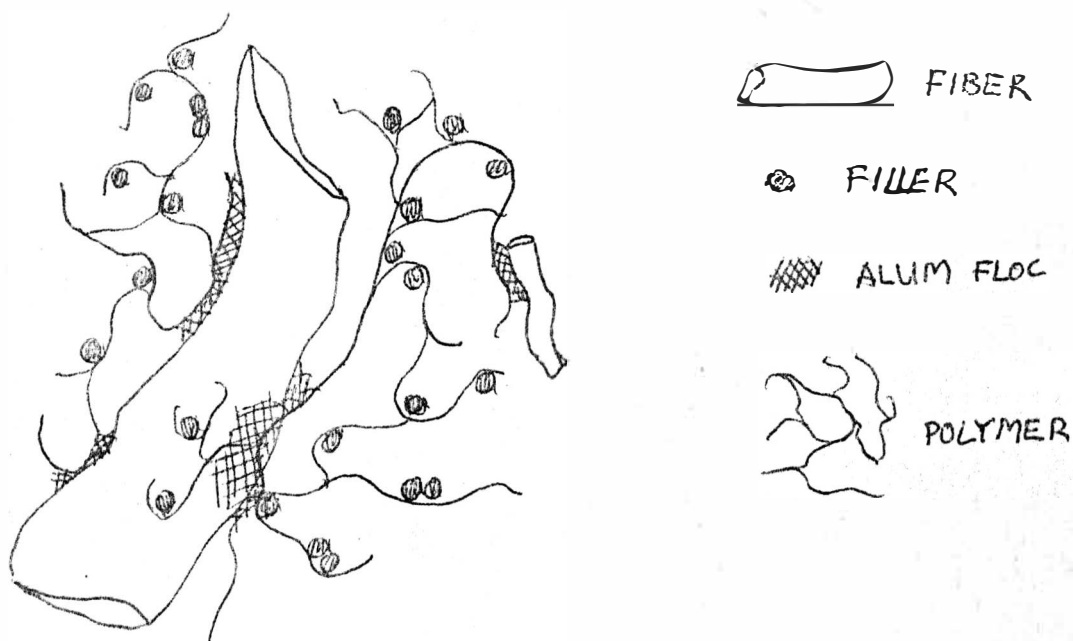
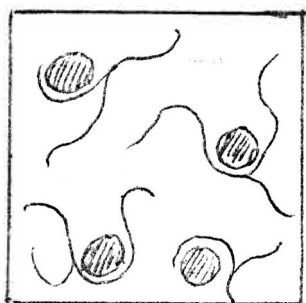


FIGURE 4

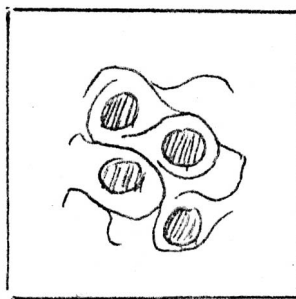


an optimum concentration at which polymers work best , and it is believed to be at about fifty per cent surface coverage by the polymers (6) (Fig. 5 ) . Flocs caused by high molecular weight polymers are known as tenacious flocs , and they are highly resistant to hydrolic shear .

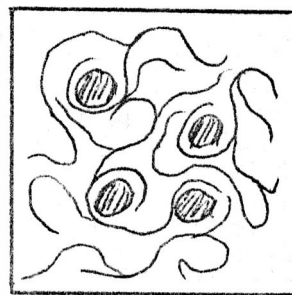
One should always be well aware of the fact that , although the use of a high molecular weight retention aid results in a fantastic improvement in flocculation , it destroys the uniformity of the sheet



LOW CONC.



OPTIMUM CONC.



EXCESS CONC.

FIGURE 5

formation . This is because the flocculations happen only in the immediate vicinity where the polymer is added ; while there might not be any flocs at all in the remaining areas of the pulp slurry . This effect is , of course , undesirable because it only results in lumps in the stock and eventually these lumps will show up on the surface of the sheets .

For a better overall improvement of the quality of the paper , retention and sheet uniform formation must compromise . Agitation has to be introduced into the slurry for a uniform flocculation distribution throughout the stock , despite of the fact that agitation will reduce the overall filler retention .

#### THE EFFECT OF AGITATION

Agitation is a creation of momentum brought about by the impulse induced by mechanical means . The transfer of this momentum from the immediate vicinity of the agitator to the bulk stock is the main vehicle of agitation . In simpler terms , it is " the creation of a state of activity such as flow or turbulence ." as defined by Parke (9) . This turbulence in a confined pulp slurry mass generates eddy currents , which Campbell (10) proved to be favorable to the formation of

flocs . However , the floc size is reduced as the average number of particles in the flocs decreases with the increasing shear rate (5) . At a given rate of shear a dynamic equilibrium is established between the flocs being continuously broken down and building up . The theory of the formation of flocs in an agitated stock is well described in the collision process (11) : In the first place , particles move relatively to one another and as a result , can undergo collisions in much the same way as do the molecules of a gas . To take a simple example , in laminar flow , the frequency of collision per unit volume in a unit time is given by the following equation .

$$f = k N^2 G v$$

Where

$f$  = the number of two-body collisions per unit volume in a unit time .

$k$  = factor depending on the shape of the particles .

$N$  = number of particles per unit volume .

$G$  = velocity gradient .

$v$  = volume of a single particle .

If conditions are favorable , two colliding

particles can cohere and form a floc . The floc can grow in size by further collisions . However , it can grow only to a certain point beyond which additional growth ceases due to the shearing action of the moving fluid . From this point of view , a complicated cross-linked molecule could easily be visualized to have better chance to collide , a better chance to trap other molecules , particles , fines and fibers ; and thus , making the forming of flocs more feasible .

However , and unfortunately , the break-down action is believed to be predominant . Britt (2) showed that agitation practically destroys filler retention in a filler-fiber system without retention aid . Muhonen and Williams (12) pointed out that at about 200 rpm, the maximum of flocculation occurs . Beyond that point flocs begin to break down , At the speed of 1000 rpm - which approximately gives the same retention as observed on the paper machine - the flocs are continuously broken down and on extended agitation time , the pulp will be completely deflocculated . The reasons for this are two fold in that the flocculant molecules are continuously coiling and uncoiling and the surface of the particles are not saturated . Thus if the free end of the flocculant chain does not have an opportunity to get in firm contact long enough to adsorb onto another particle due

to vigorous agitation , it will cohere to the same one, and therefore , less bridging is formed and less flocculation (13) . The extreme is that one polymer molecule will stick to one particle and there is no bridging activity . Another reason for this is the breaking of the chain length of the polymer , the process being irreversible , resulting in less and less effective bridging action as agitation time expands .

Still , it is essential that some degree of agitation exists during the flocculation process for the following reasons : The flocculant is adsorbed strongly and irreversibly onto particle surfaces . If there is no agitation , the flocculant will adsorb intensively to the particles just around the point of addition only, leaving other particles unflocculated in the body of the system . The result is that , although there is a tremendous degree of flocculation , the retention is still poor and the sheet formation is badly ruined . Moreover , the natural contact between the particles and the flocculants is not sufficient to cause bridging action to occur . Particles have to be brought into intimate contact with the flocculants in order to establish firm bondings .

Different degrees of agitation could be controlled by varying the points of addition of the poly-

mer , by changing the propellers of the agitator , or by alternating the speed of the agitator to obtain the desired effect .

### THE EFFECT OF ZETA POTENTIAL

Most filler particles dispersed in water are invariably charged , either by ionization or by preferential adsorption of one ion or another ; and since the particles are identical , their charge will be the same. The particles could be visualized to have ionic layers around the surfaces . The first layer of ions adsorbed to the surface of a particle will result in the attraction of a second layer of the counter ions which is less in number than the first ions . Other layers may continue to adsorb to the second layer in the same manner but only the first two are considered stable enough to remain with the particles as they move around in the solvent ( Fig. 6 ) .

As a result of this ion adsorption phenomenon, the solvent media becomes deficient in the particular charge that have adsorbed onto the particles , which , in turn , have in abundance of this same charge . A potential between the particles and solvent , then , develops and is popularly known as zeta potential (14) .

It was indicated by Thode (15) that fillers as well as fibers dispersed in water develop negative zeta potential . The charge of the potential is an indication of the surface dominating ions . Negative potential indicates anions dominating the outside of the potential gradient ; whereas positive potential shows the domination of cations (16) . The flocculation is proved to be most effective when the zeta potential approaches the iso-electric point , which means that zeta potential is approaching zero (17) .

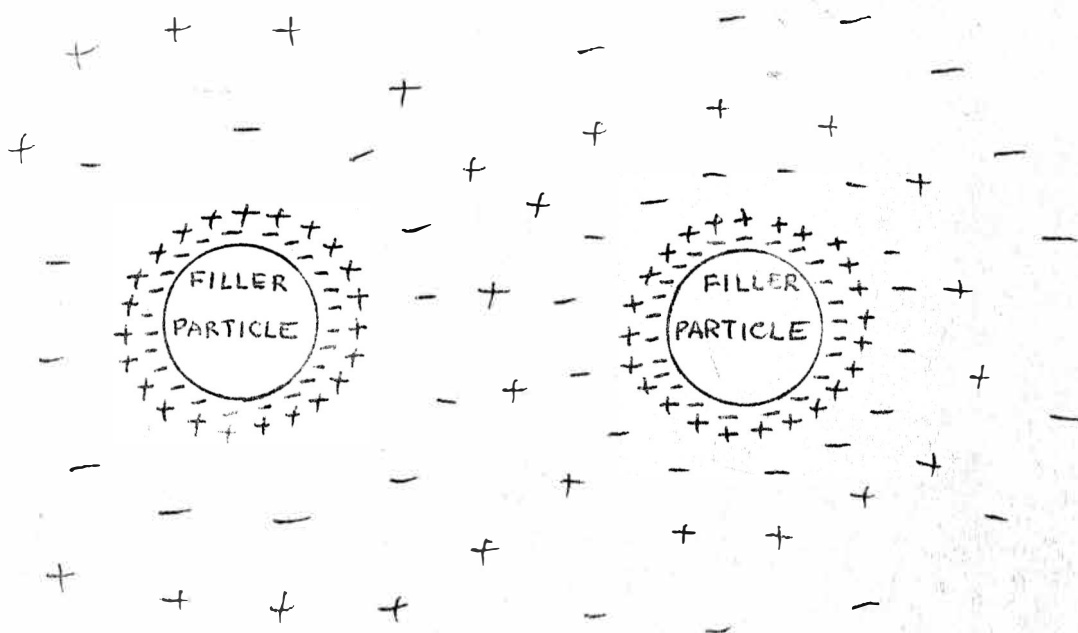


FIGURE 6

An obvious conclusion could be drawn from the above findings is that polyvalent ions of opposite charge to that on the surface of the particles will be very effective in decreasing or even eliminating the electrostatic charge barrier between particles due to zeta potential . Oakleaf (18) specifically pointed out that , with the use of cationic agents , zeta potential could be changed to positive values which is more favorable for flocculations to occur .

Willems revealed in a study of filler retention that zeta potential is highly dependent on pH (19). Strazdins (20) seems to agree with him in saying that, by increasing the pH from 6.0 to 8.5 , the electronegative potential is also increased . The case is , however , that in the pH range of the paper making process, both fillers and fibers in the stock develop a negative zeta potential . This illustrates the difficulty in achieving a good filler retention . Another problem is that zeta potential can hardly be controlled because zeta potential cannot be measured on-line . Usually a portion of the stock is screened , the filtrate is used for the measurement . One method of measuring zeta potential is electrophoresis , which uses a special cell containing the filtrate to be viewed with a microscope. The velocity of the particles is measured while a known



voltage is introduced across the media . From there the electrophoretic mobility is figured out and converted to zeta potential (20) . Other methods , such as electromosers and streaming current detection , are also popularly used .

### COMPARISON OF THE THREE EFFECTS

We have , so far , discussed separately the effects of molecular weight , of agitation and of zeta potential . In reality , all of them co-exist in the problem of fibers and fillers retention . It is a matter of compromising , because we cannot get the maximum effects for all of them . This is not an easy task since there is no known formula of application to be used . Each paper mill has to determine ofr itself what the optimum combination is .

An extensive dosage of polymer does not guarantee best results because of the possible poor flocculation . Sheet formation is likely to be upset , too . The potential problem increases if the degree of agitation is not well adjusted accordingly . An inadequate degree of agitation could cause serious problem of sheet formation , On the other hand , severe agitation is a waste of energy and reduction of fillers and fibers re-

tention . Foam formation also threatens with excess agitation . The general rule for applying polymers is that the flocculants should be introduced to the stock beyond the points of severe turbulence . The importance of zeta potential , compared to the other two parameters , is still controversial . Arvenla (8) suggested that it is the total amount of charge contributed by the polymer that determines the amount of retention and that molecular weight plays only a secondary role . Whether this suggestion is totally true or not , it surely emphasize the importance of the matter . The control of zeta potential is , however , a difficult job to perform since , by varying the pH , there might be some unwanted side-effects .  $\text{CaCO}_3$  , for example , is very sensitive to pH , and it could possibly decompose in acidic solution . Abrasion is also another problem to be considered .

Perhaps , it would be better to state any conclusion after the experiments are carried out , and the results are gathered .

## EXPERIMENTAL DESIGN

This experiment will be devoted to the investigation of the following points :

— The influences on filler retention of an electrolyte ; of low , medium and high molecular weight polymers which have the same chemical structure .  
Then , the best retention aid of each category will be selected out and compared on plotted curves .

— The effects on retention of low , high turbulence , and shear .

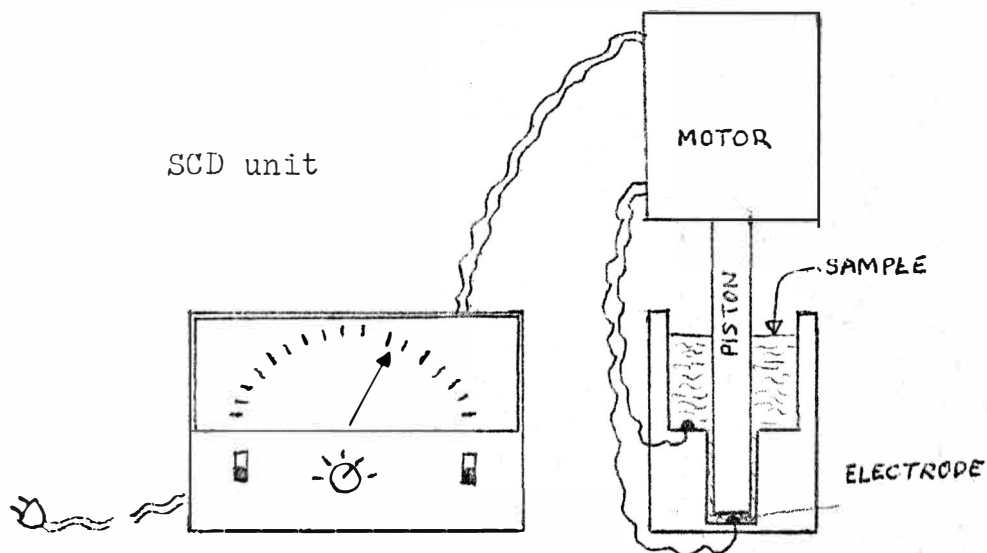
— The attempts to vary Zeta potential of the pulp stock to observe the changes in filler retention .

— Last of all , these three effects will be compared to find out which one is more predominant .

## EQUIPMENTS

Following is the list of the equipments used in this experiment .

- 1) Noble and Wood paper machine .
- 2) Allis Chalmers beater .
- 3) pH meter .
- 4) Hermann mixer .
- 5) Wemco mixer .
- 6) Stream Current Detector .



## MATERIALS

1) Pulp : Combination of 50% hard wood Kraft and 50% soft wood Kraft .

2) Filler : Titanium dioxide (  $\text{TiO}_2$  ) .

3) Retention aids :

— Electrolyte : Alum .

— Low molecular weight polymers ( molecular weights range from 20 to 30 thousand ) :

Nalco 7607 : A cationic , high charge density polymer of acrylamide , pH = 3.5 .

Nalco 634 : A cationic , high charge density polymer of acrylamide , pH = 9.5 .

— Medium molecular weight polymers ( molecular weights range from 4 to 5 million ) :

Nalco 7661 : A cationic polymer of acrylamide pH = 10.0 .

Nalco 7663 : A cationic polymer of acrylamide pH = 6.7 .

— High molecular weight polymers ( molecular weights range from 7 to 14 million ) :

Nalco 625 : A anionic polymer of acrylamide pH = 7.0 .

Nalco 623-SC : A anionic polymer of acrylamide pH = 6.8 .

Nalco 7654-SC : A cationic polymer of acrylamide , pH = 6.7 .

#### EXPERIMENTAL PROCEDURE

A mixture of 50% of hard wood Kraft and 50% of soft wood Kraft of dry pulp were weighed out proportionally .

The dry pulp was , then , beaten for 15 minutes .

The stock was diluted down to .35% consistency.

Titanium dioxide filler was added to the diluted stock at the ratio of 1.5g  $\text{TiO}_2$  per 7.0g dry fiber ( one sheet ) .

Blanks were made every time a new batch of dilute stock was prepared .

Different retention aids were added , separately and combinationally , at different dosages .

Handsheets were made .

White water were sampled for the measurements of pH and zeta potential with the pH meter and the SCD respectively .

Handsheets were weighed .

Averages and percentages of retention were computed .

During this experimental process , the following factors were maintained as constantly as possible to minimize possible errors .

Use of the same Noble and Wood machine , and the same two wires .

Use of the same beater with the same weight .

Pressing : Once .

Drying : Twice .

Dryer speed setting : 2 .

Dryer temperature setting : 245 degrees Fahrenheit .

For the study of agitation , different types of mixers were used to generate various degrees of turbulence into the stock . Of course , different retention aids were employed to observe any different effect . First of all , the regular mixer attached to the Noble and Wood machine was used . Then the Hermann mixer was used in addition to the regular mixer for 15 minutes . Finally , shear was introduced to the stock by the use of the Wemco mixer for 15 minutes , also .

Sheets were made in the same procedure described above .

Necessary computations were performed .

As an attempt to investigate the effect of zeta potential , Alum was applied at different levels to hopefully alter the zeta potential values , since it has a high valency . Various amounts of dilute  $H_2SO_4$  acid and dilute NaOH were also used separately to control the pH of the stock and, thus , control the zeta potential , supposedly at least . Nalco 7654-SC and alum were used as retention aids at 1#/T and 5% , respectively . Furthermore , pH and zeta potential values were recorded during all other runs of the experiments of molecular weight effect .



## RESULTS

### EFFECT OF MOLECULAR WEIGHT

The retention of filler and fiber was noticeably increased , from 0.0% to 12.0% ( Table I ) , by the use of a simple electrolyte , namely alum , After reaching the maximum , however , the retention started to go down , although the amount of electrolyte was increased.

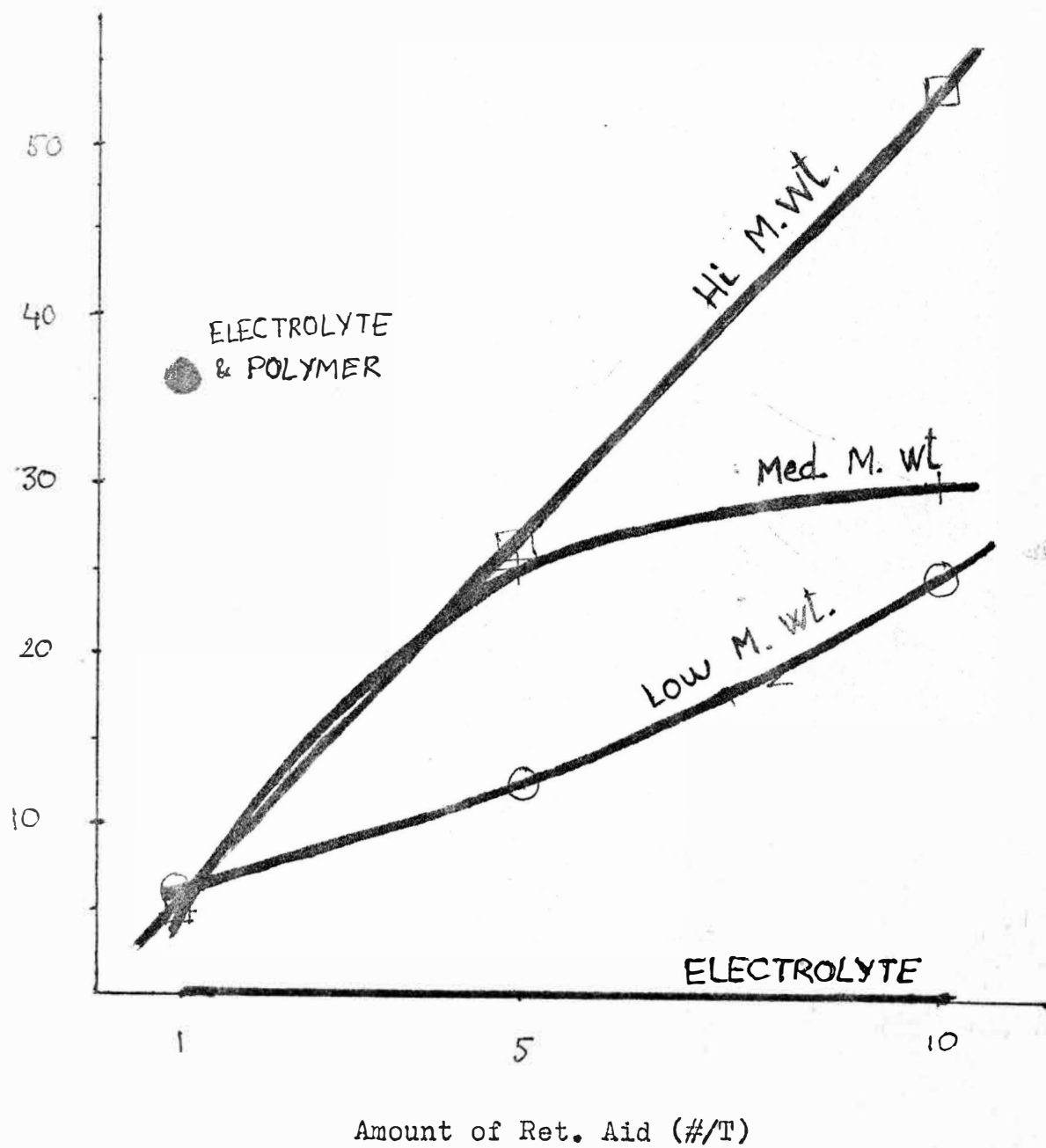
Low molecular weight polymer produced much better retention ( Table II and III ) . 10#/T of Nalco 634 doubled the retention produced by alum , and 10#/T of Nalco 7607 almost tripled it . The retention was also increased as the amount of polymer was increased .

Medium molecular weight polymer , Nalco 7663 , yielded similar retention as did Nalco 7607 . While Nalco 7661 did not perform very well ( Table IV and V ). However , there was still an increase in retention as the amount of polymer was increased .

Anionic high molecular weight polymers - being Nalco 623-SC and Nalco 625 - gave pretty good retention . Nalco 623-SC yielded up to 36.7% at the dosage of 5#/T only ( Table VI and VII ) .

The best retention of all was obtained with the use of Nalco 7654-SC , a cationic high molecular

Percent Retention



weight polymer . There was a definite increase in retention recorded : 53.3% ( Table VIII ) .

The combination of 5% by weight of alum , which yielded 0.0% retention all by itself , and 1#/T of Nalco 7654-SC , which was the least amount of polymer added , resulted in a marvelous retention of 36.7% ( Table IX ) .

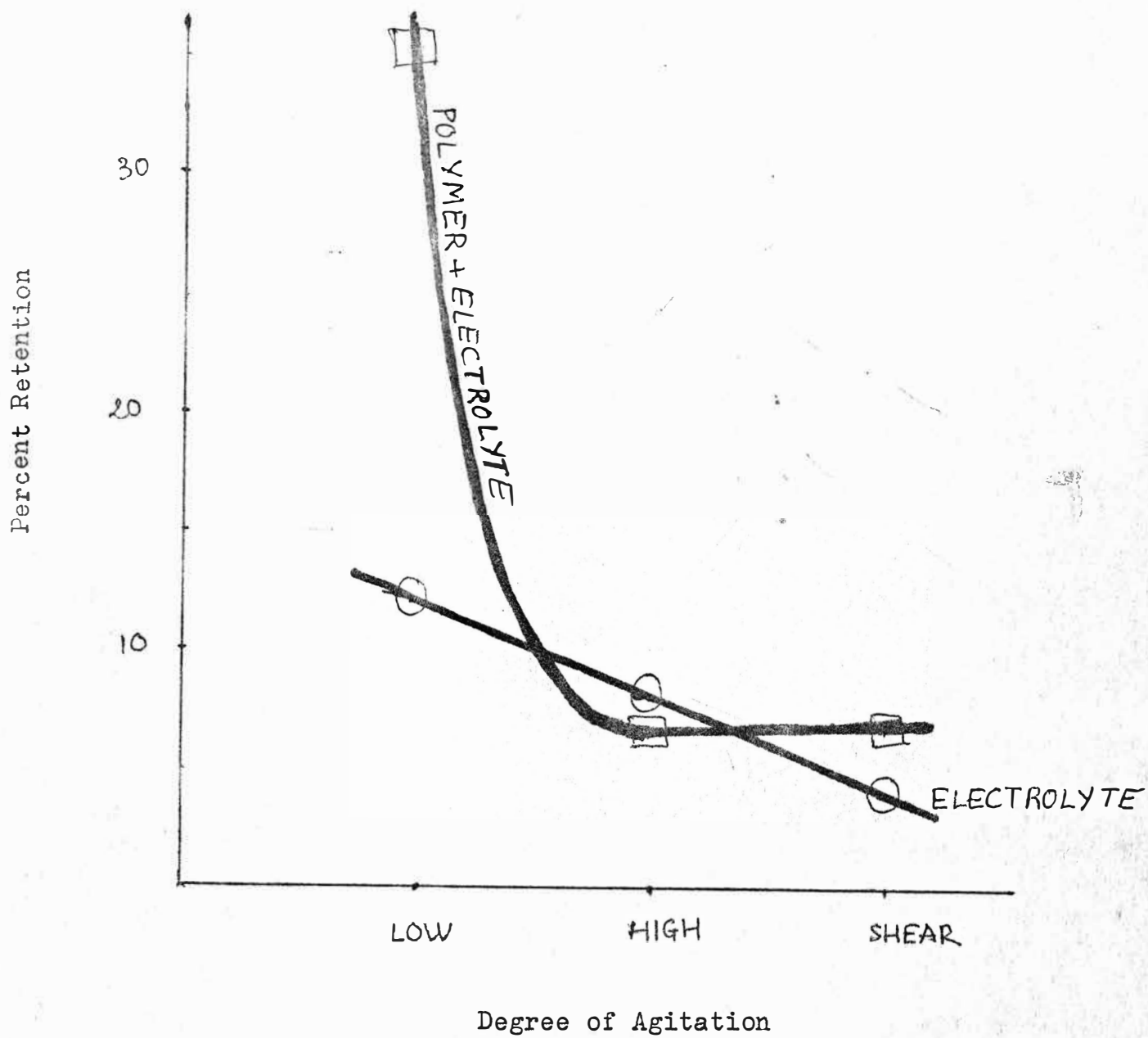
#### THE EFFECT OF AGITATION

Significant reduction of retention was recorded , when agitation was introduced into the system where alum was the retention aid . When shear was applied the retention went down to 4% ( Table X ) .

In the dual retention aid system , the destruction effect was less severe . The percentage of retention went down similarly . But when it reached the minimum value of 6.7% , the percentage of retention leveled out , even though shear was applied ( Table XI ) .

#### THE EFFECT OF ZETA POTENTIAL

When different amounts of alum were added to the stock , there was a noticeable change in zeta potential values , It moved closer toward the iso-electric point , and the average weights of the sheets were higher - meaning higher retention ( Table XII ) .



The addition of dilute solution of  $H_2SO_4$  acid did not seem to effect the zeta potential values . However retention was slightly reduced ( Table XIII ) .

On the other hand , the percentage of retention was slightly increased with the addition of dilute solution of NaOH , and the zeta potential values were shifted more to the positive side ( Table XIV ) .

With the addition of other polymers , zeta potential values changed a little but not significant enough to account for any change in retention ( Tables XV to XXI ) .

## DISCUSSION

As it was expected , the percentage of retention of filler and fiber was greatly improved with the use of retention aids . There was an obvious difference in the behavior of the electrolyte and that of the polymers . Alum , as an electrolyte , produced a limited level of retention at a much higher dosage . An alum dosage of 10% by weight of the dry stock would be 220 pounds per ton , approximately . It is too high a dosage to be feasible for actual application .

Polymers , on the other hand , yielded higher flocculation and better retention at a much lower dosage . As the molecular weights of the polymers increased , there were observable improvements in flocculation and clearness of the white water . At low molecular weight , fine flocs could be detected in the stock , and the white water was milk-like . At medium molecular weight , better clearness of white water was observed . And at high molecular weight , large flocs could be easily seen in the stock , the white water was much clearer . In the case of Nalco 7654-SC , tremendous flocculation in the stock was noted , Numerous flocs were visible in a clear water solution . White water which was sampled

out for pH and zeta measurements showed great clearness .

Some deviations from the general trend were recorded also . One was the case of Nalco 7661 . The retention level was quite low ( 9.3% ) for a medium molecular weight polymer . The only observable chemical property that might possibly account for its behavior was that the pH of the polymer was 10.0 , which was quite different from the others . Another case was that of Nalco 625 . The percentage of retention was a little low ( 14.7% ) compared to those of the other high molecular weight polymers . An observation was made that the polymer was an anionic one .

These deviations suggest that , for a given paper making process , there is a particular retention aid , or combination of retention aids , that works best . So the selecting of retention aids is also essential .

The best result must be attributed to the dual retention aid system of alum and Nalco 7654-SC.. This is a firm verification of the molecular weight theories presented in the literature review .

As for the effect of agitation , the data proved that turbulence broke down floc formation and retention . This effect was also expected . In the

stock with alum as retention aid alone , agitation practically destroyed retention especially when shear was present . The pulp stock looked like one without retention aid !

With the use of the dual retention aid system , the deflocculation action was less severe . Retention was higher , and most significantly , the retention leveled out when the minimum value of 6.7% was reached .

Zeta potential was most effectively varied by alum , according to the experiment results . Subsequent increasing amounts of alum added to the stock shifted the zeta potential values closer toward the iso-electric point , and the percentage of retention was increased .

Dilute solution of acid did not change zeta potential , but it seemed to destroy coagulation , and thus reduced retention . When pH was raised from 7.15 to 9.65 by the addition of dilute solution of NaOH , zeta potential values were increased from +.75 to +1.0 . The retention was slightly increased , This is a very close parallel with the suggestion made by Strazdins discussed earlier .

There was no significant change in zeta potential that encouraged any conclusion , when polymers were added . The percentage of retention was increased



but that was more likely the effect of the molecular weight of the polymers rather than that of the potential .

## CONCLUSION

The role of molecular weight of retention aid in filler retention is undoubtedly important . Great improvements could result from the right employment of retention aids , depending on each individual paper making process . Usually , the best way is to use a dual retention aid system of an electrolyte and a high molecular weight polymer .

It could be generally said that higher molecular weight polymer produces better percentage of retention , and that increasing amount of polymer would result in increasing retention .

It is clear that agitation reduces the percentage of retention . Shear has a severe effect on coagulation and flocculation . Floc size is reduced or even destroyed in a pulp stock with electrolyte only . The use of high molecular weight polymers as retention aids would help a great deal to resist this destruction action .

A conclusion could be drawn , with caution , that zeta potential could be varied most effectively by the use of high valency electrolytes , and that coagulation and flocculation is favorable when zeta po-

tential is near the iso-electric point , or on the positive side .

With the obtained data , one could make a conclusive statement that the molecular weight of the retention aid is most predominant in the attempt to improve filler retention . Zeta potential does not seem to cause a major change in retention . The effect of Zeta potential is a little doubtful because of the fact that pH is changed when a change in Zeta is made , so , it could have been the change in acidity that caused , or contributed to the cause of the change in retention. Agitation , on the other hand , gives negative results in filler retention , It is , however , a necessity because of its positive effect on formation of the sheet.

TABULATED DATA

NOTE : The weight unit in this data section is gram  
unless otherwise indicated .

TABLE I

ELECTROLYTE : ALUM

RUN	BLANK	5%	10%	20%
1	7.04	7.02	7.52	7.15
2	7.33	7.37	7.40	7.28
3	7.30	7.21	7.28	7.45
4	7.39	7.27	7.28	7.45
5	7.00	6.96	7.48	7.40
Avg.	7.21	7.17	7.39	7.35
Ret.		0.0%	12.0%	9.3%

TABLE II

POLYMER : NALCO 634

RUN	BLANK	1#/T	5#/T	10#/T
1	8.00	8.27	8.30	8.35
2	7.85	8.68	7.79	8.35
3	7.95	7.88	8.00	8.40
4	7.90	8.29	8.48	8.70
5	8.10	8.26	8.30	7.93
Avg.	7.98	8.08	8.17	8.35
Ret.		6.7%	12.7%	24.7%

TABLE III

POLYMER : NALCO 7607

RUN	BLANK	1#/T	5#/T	10#/T
1	7.08	7.73	7.85	7.80
2	7.04	7.19	7.49	7.58
3	7.13	7.29	7.58	7.61
4	7.30	7.38	7.65	7.75
5	7.53	7.61	7.58	7.90
Avg.	7.23	7.44	7.63	7.73
Ret.		14%	26.7%	33.3%

TABLE IV

POLYMER : NALCO 7661

RUN	BLANK	1#/T	5#/#	10#/T
1	7.50	7.35	7.60	7.57
2	7.46	7.48	7.52	7.25
3	7.25	7.22	7.30	7.71
4	7.21	7.09	7.27	7.42
5	6.92	6.99	7.15	7.12
Avg.	7.27	7.23	7.37	7.41
Ret.		0.0%	6.7%	9.3%



TABLE V

POLYMER : NALCO 7663

RUN	BLANK	1#/T	5#/T	10#/T
1	7.56	8.16	7.61	8.55
2	7.83	7.80	8.28	8.63
3	7.87	8.20	8.22	8.42
4	8.11	8.10	8.47	8.31
5	7.97	7.44	8.25	8.32
Avg.	7.87	7.94	8.25	8.32
Ret.		4.7%	25.3%	30.0%

TABLE VI

POLYMER : NALCO 623- S C

RUN	BLANK	1#/T	5#/T	10#/T
1	7.51	7.89	8.24	8.08
2	7.42	7.80	8.39	7.99
3	7.48	7.68	7.92	8.02
4	7.57	7.50	7.99	7.90
5	7.45	7.40	7.65	7.75
Avg.	7.49	7.67	8.04	7.95
Ret.		12.0%	36.7%	30.7%

TABLE VII

POLYMER : NALCO 625

RUN	BLANK	1#/T	5#/T	10#/T
1	7.67	7.95	8.05	7.92
2	7.72	7.73	7.92	8.03
3	7.76	7.61	7.97	7.95
4	7.64	7.68	7.85	7.80
5	7.41	7.30	7.50	7.52
Avg.	7.64	7.65	7.86	7.85
Ret.		.7%	14.7%	14.0%

TABLE VIII

POLYMER : NALCO 7654-SC

RUN	BLANK	1#/T	5#/T	10#/T
1	7.04	7.28	7.82	7.75
2	7.01	7.30	7.52	7.73
3	7.22	7.31	7.58	8.43
4	7.32	7.21	7.63	7.85
5	7.35	7.27	7.42	8.19
Avg.	7.19	7.27	7.59	7.99
Ret.		5.3%	26.7%	53.3%

TABLE IX

COMBINATION of 1#/T of  
NALCO 7654 and  
5% by weight of ALUM

RUN	BLANK	COMBINATION
1	7.80	8.41
2	7.60	8.34
3	7.67	8.05
4	7.62	8.05
5	7.47	8.05
Avg.	7.63	8.18
Ret.		36.7%

TABLE X

## AGITATION EFFECT ON ALUM AS RETENTION AID

RUN	BLANK	A	B	C
1	7.42	7.90	7.61	7.50
2	7.50	7.57	7.39	7.34
3	7.25	7.23	7.31	7.35
4	7.19	7.08	7.32	7.21
5	6.81	7.29	7.10	7.04
Avg.	7.23	7.41	7.35	7.29
Ret.		12.0%	8.0%	4.0%

A = 10% by weight alum, regular mixing .

B = 10% by weight alum , Hermann mixer at high speed .

C = 10% by weight alum , Wemco shear mixer .

TABLE XI

## AGITATION EFFECT ON POLYMER and ALUM

RUN	BLANK	D	E	F
1	7.80	8.41	8.00	7.93
2	7.60	8.34	7.80	7.60
3	7.67	8.05	7.84	7.83
4	7.62	8.05	7.68	7.68
5	7.47	8.05	7.40	7.66
Avg.	7.64	8.18	7.74	7.74
Ret.		36.0%	6.7%	6.7%

D = 5% alum + 1#/T Nalco 7654 , regular mixing .

E = 5% alum + 1#/T Nalco 7654 , Hermann mixer at high speed.

D = 5% alum + 1#/T Nalco 7654 , Wemco shear mixer .

TABLE XII

## VARYING ZETA POTENTIAL WITH ALUM

	BLANK	5%	10%	20%
Z	+1.0	+ .9	+ .7	+ .4
pH	7.25	7.20	6.90	6.80
Wt.	7.21	7.17	7.39	7.35



TABLE XIII

VARYING ZETA POTENTIAL (Z) WITH ACID\*\*

	BLANK	5ml	15ml	30ml	50ml
Z	+ .8	+ .8	+ .8	+ .8	+ .8
pH	7.17	6.99	6.76	6.46	6.28
Wt.	7.60	7.59	7.53	7.48	7.42

\*\* Dilute solution of  $\text{H}_2\text{SO}_4$

TABLE XIV

VARYING ZETA POTENTIAL (Z) WITH BASE\*\*

	BLANK	5ml	15ml	30ml	50ml
Z	+ .75	+ .75	+ .87	+ 1.0	+ 1.0
pH	7.15	7.90	8.70	9.25	9.65
Wt.	7.60	7.80	7.60	7.60	8.00

\*\* Dilute solution of NaOH

TABLE XV

ZETA POTENTIAL VALUES , WITH THE ADDITION OF 634

	BLANK	1#/T	5#/T	10#/T
Z	+1.2	+.8	+.7	+.7
pH	7.30	7.10	7.10	7.10
Wt.	7.98	8.08	8.17	8.35

TABLE XVI

ZETA POTENTIAL VALUES , WITH THE ADDITION OF 7607

	BLANK	1#/T	5#/T	10#/T
Z	+1.1	+ .8	+ .7	+ .8
pH	7.25	7.10	7.15	7.20
Wt.	7.23	7.44	7.63	7.73

TABLE XVII

ZETA POTENTIAL VALUES , WITH THE ADDITION OF 7661

	BLANK	1#/T	5#/T	10#/T
Z	+1.2	+ .9	+ .9	+1.3
pH	7.30	7.40	7.35	7.40
Wt.	7.27	7.23	7.37	7.41

TABLE XVIII

ZETA POTENTIAL VALUES , WITH THE ADDITION OF 7663

	BLANK	1#/T	5#/T	10#/T
Z	+1.0	+ .8	+ .8	+ .7
pH	7.30	7.20	7.30	7.30
Wt.	7.87	7.94	8.25	8.32

TABLE XIX

ZETA POTENTIAL VALUES , WITH THE ADDITION OF 623-SC

	BLANK	1#/T	5#/T	10#/T
Z	+1.2	+ .9	+ .9	+ .9
pH	7.30	7.65	7.65	7.60
Wt.	7.49	7.67	8.04	7.95

TABLE XX

ZETA POTENTIAL VALUES , WITH THE ADDITION OF 625

	BLANK	1#/T	5#/T	10#/T
Z	+1.2	+ .9	+1.0	+1.1
pH	7.25	7.20	7.35	7.40
Wt.	7.64	7.65	7.86	7.85



TABLE XXI

ZETA POTENTIAL VALUES , WITH THE ADDITION OF 7654-SC

	BLANK	1#/T	5#/T	10#/T
Z	+1.0	+ .4	+ .8	+ .6
pH	7.20	7.00	7.10	7.35
Wt.	7.19	7.27	7.59	7.99

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